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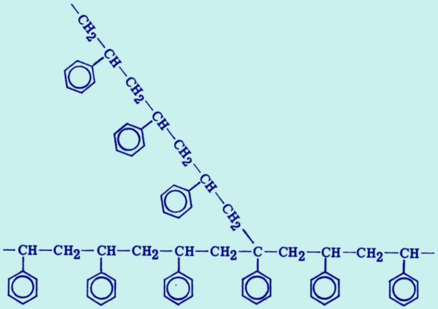

PLASTICS

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PLASTICS

Plastics have become an essential material in our lives. Look about you almost anywhere and you will see something completely or partially made of plastic—a bag, a button, a plate, car top, pocketbook or television set. Because of their special characteristics and versatility, plastics, like the natural products, wood, metals and natural fibers, are now one of the important basic materials upon which our modern world depends. Their use extends into virtually every aspect of our lives—from household necessities to hospital equipment; from toys to roof tops.

What are plastics?

Plastics are a family of organic compounds of high molecular weight called polymers. Polymers are giant molecules made up of many (poly) parts (mers) or units of simple organic compounds linked together in a chain. The single units or monomers composing a chain may number into the tens of thousands or more. The process by which these monomers combine to form the macromolecules is referred to as polymerization.

The structure of a polymer chain may be linear, branched or crosslinked. If the

monomers in the compound are linked together end to end in a chain, the molecule is a linear polymer. Under certain conditions short chains of monomers may become attached to central points in the long main polymer chains and extend outward from them like branches of a tree. They are then called branched polymer chains. Linear polymers may also become linked to each other along their lengths by side chains. Such polymers are said to be crosslinked. The three types are illustrated diagrammatically in Figure 1.

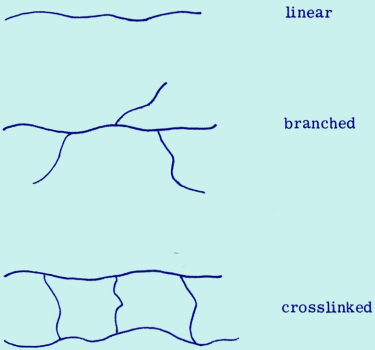

Fig. 1.

Branching and crosslinking have a great effect on the properties of a polymer. Branching makes a polymer bulkier and affects its crystalline nature especially, while crosslinking makes a polymer more rigid and stable by restricting the movement of the chains.

One of the greatest advantages of plastics is that they can be molded into desired shapes fairly simply by applying heat and at less cost as compared with metals and woods.

They are divided into two classes, thermoplastics and thermosets. Thermoplastics are plastics that after being heated and formed and then cooled may be reheated and reshaped into another form. They may be heated, molded and cooled repeatedly without affecting their original properties.

A thermoset plastic once heated and shaped cannot be remolded after cooling. Its shape is permanent. When thermosets are heated, they become crosslinked to form a three-dimensional network of polymers and the result is a rigid polymer that does not regain its plasticity on reheating.

Plastics include a wide range of materials having different properties—fibers,

flexible plastics, rigid plastics, foams and elastomers.

Included in this unit are specimens representative of each of the above groups except fibers and through experimentation with them you will be able to observe their interesting characteristics.

First identify your specimens.

WHITE PRINTING PAPER—Polyethylene sheet; white; 2 x 4 inches in size.

TRANSPARENT FILM—Polyvinyl alcohol; water soluble.

GLASS-LIKE BEADS—Tiny beads of expandable polystyrene foam; in polyethylene bag.

SHOE PLATE—Small black curved plate with staple; in transparent polycel bag; thermoplastic polyurethane elastomer.

CAR BODY—Made of polycarbonate.

LIVING HINGE—Made of polyallomer.

POLYETHYLENE

You are all familiar with the transparent plastic bags used in the household and by manufacturers for packaging various objects. These bags, like the one in which the expandable polystyrene beads are enclosed, are frequently made of polyethylene, a flexible plastic, whose transparency

and resistance to water and grease make it one of the most useful materials for our daily needs. But this application is only one of the many uses of polyethylene.

Polyethylene is a thermoplastic polymer consisting of a chain of from 900 to thousands of ethylene ($CH_2{=}CH_2$) molecules, or monomers, linked together. Each of the carbon atoms in an ethylene molecule has two hydrogen atoms attached to it. When ethylene is polymerized, the carbons become linked together to form the large molecules of polyethylene (Fig. 2).

$$\vdots\, CH_2-CH_2 \,\vdots\, CH_2-CH_2 \,\vdots\, CH_2-CH_2 \,\vdots$$

or

$$\begin{array}{c|ccc|ccc|ccc|}
 & H & & H & H & & H & H & & H \\
- & C & - & C & C & - & C & C & - & C \\
 & H & & H & H & & H & H & & H
\end{array}$$

Fig. 2

(The dotted lines mark off the monomer units.)

Polyethylene chains may be linear, branched or crosslinked.

Experiment 1. Examine your specimen of white polyethylene paper, feeling its smooth surface and noting its color

and flexibility. The polyethylene paper is made from linear polyethylene, aligned or oriented to form a close-packed high density product.

Linear polyethylene can be more closely packed and therefore makes a denser material than the branched or crosslinked polyethylene. To visualize why this is so, obtain some straight sticks or unbranched limbs from a bush or tree to represent linear chains. Stack them side by side as close together as you can. Note that they can be aligned in a close-packed bundle.

Now take an equal number of branched limbs. These will represent branched chains. Stack these together. Observe how much more space they occupy and that they cannot be aligned one against the other closely because the branches get in the way. Which bundle would you say is the most dense?

Polyethylene is divided into three general classifications—low density, medium density and high density—depending upon the closeness of packing of the carbon chains.

The white polyethylene paper in your unit is a high density linear polyethylene called AcroArt$_{\text{TM}}$ produced by The Mead

Corporation, Dayton, Ohio, who contributed your specimen. AcroArt was developed in cooperation with Union Carbide Corporation, New York.

Experiment 2. Try to tear your piece of polyethylene paper. Can you? The close-packed molecules make the paper tough and give it great resistance to tear, thus making it suitable for such uses as book covers, maps, charts, tags and labels.

Experiment 3. Repeatedly fold and unfold the paper. Note that the crease does not break. AcroArt can be folded more than 20,000 times without damage.

Experiment 4. Hold the paper up against the light. You will find that no light passes through. It is opaque. Polyethylene resin is transparent, but fillers and pigments have been added to make AcroArt opaque and give it its white color.

Experiment 5. Try to write on the polyethylene bag in your unit (you can do this experiment without emptying the contents) with a pencil. Can you? Since polyethylene film is much softer than pencil lead, it cannot normally be written on with a pencil.

Use the same pencil and write your

name on the AcroArt. Can you write on it readily? The filler and pigments present in the paper make this possible. As you write, some of the lead from the pencil is scratched off by the filler, leaving a mark.

Experiment 6. Write on the paper with a ballpoint pen. Note how well it accepts the ink without smearing.

AcroArt is also printable. Regular printing ink does not ordinarily adhere to polyethylene, but the polyethylene paper has been treated to take print.

Experiment 7. Place a drop of water on the polyethylene paper. Does it absorb it? The material is impervious to water, just as is the transparent polyethylene bag.

Rub a little butter or other oily substance across the paper's surface. Then rub it off. Note that grease does not penetrate the surface. Polyethylene resists both water and oils.

In the manufacture of AcroArt, fillers, pigments and materials to prevent the accumulation of static electricity and to protect the surface from light and heat are mixed with polyethylene resin using powerful mixers.

After the polyethylene and fillers have been mixed together, the polymer is

pushed through a die and made into small pellets. These pellets are then processed with controlled heat and pressure to make AcroArt.

Polyethylene may be formed by one of two extrusion processes: cast or blown. The blown film process is used to make AcroArt. In this method, the polyethylene mixture is extruded through a circular slot in a die. It emerges in tubular form closed at one end. As it is extruded, it is filled with air, forming a large sausage-shaped bubble.

In order to orient the molecules properly the sheet must be stretched in both directions. The air injected into the tube does just that. As the polyethylene is inflated, it is stretched in two directions at once aligning the molecules.

The blown film is passed through a series of rolls and flattened. The flattened tube is slit along the sides to form two separate continuous sheets or webs. These are then cut into sheets of desired length or rolled up into rolls. Sheets of AcroArt may be in thicknesses from 3 to 10 mils. The specimen in your unit is 10 mils thick.

The qualities which you have observed in your experiments make AcroArt useful in innumerable ways, including such di-

verse applications as protection against rain, movie projection screens and place mats. Its printability adds to the variety of uses to which it can be applied.

POLYVINYL ALCOHOL

Polyvinyl alcohol is a polymer having a hydroxyl (OH) group in every other carbon atom.

This polymer is not produced by polymerization as is polyethylene, since the monomer vinyl alcohol ($-CH_2CHOH-$) is an unstable compound and does not exist alone. First, vinyl acetate is polymerized and then the acetate group ($OCOCH_3$) in polyvinyl acetate is substituted with the OH group to get polyvinyl alcohol (Fig. 3). This substitution is known as hydrolysis.

$$-\underset{\displaystyle OH}{\underset{|}{CH}}-CH_2-\underset{\displaystyle OH}{\underset{|}{CH}}-CH_2-$$

polyvinyl alcohol

Fig. 3

The polyvinyl alcohol precipitates out in granules and is filtered, washed and dried.

The length of the polymer chain or

molecular weight of the polyvinyl alcohol depends upon the extent of polymerization of the polyvinyl acetate.

The hydrolysis of polyvinyl acetate may be stopped at convenient times during the manufacturing process to produce qualities desired. When carried to 95%, the product is considered to be completely hydrolyzed.

Experiment 8. Feel the polyvinyl alcohol film in your unit. Note its thickness and transparency.

Place a drop of water near one corner of the film. What happens? The drop spreads a little and then disappears into the film. Does the film expand and become crinkled? Water permeates the film rapidly since the polymer is made in water.

Experiment 9. Cut a one-half-inch square piece from your polyvinyl alcohol film and place it in water at room temperature.

Cut another piece of the same size and place it in hot water from the tap.

Allow them to stand for several minutes. What happens to the films? Is some of each of the specimens dissolved? Which of the films, the one in cold or the one in hot water dissolved the most?

Note the consistency of both. Have they become gelatinous?

Experiment 10. Heat a small amount of water to boiling and place in it a ½-inch square piece of the film while the water is boiling rapidly. What happens to the film? Does it disappear almost immediately?

There are two types of polyvinyl alcohol film—one which dissolves in cold water and the other in very hot water. Your specimen is of the latter variety.

Experiment 11. Cut a one-by-one-inch piece of polyvinyl alcohol film and try to stretch it. Note its high tensile strength. The greater the amount of hydrolysis in the preparation of the film the greater its tensile strength.

Now dampen the square of film in cold water. Does its stretchability increase? Soak it in cold water for about an hour and then stretch it again. The more water it absorbs, the more readily it stretches. Eventually the film becomes weakened and will break when stretched.

Experiment 12. Try to tear the dry film. Polyvinyl alcohol has great tear resistance. Tear resistance also increases with increased hydrolysis.

Experiment 13. Polyvinyl alcohol film does not need curing in its manufacture. Only evaporation of water from the solution is necessary.

Dissolve a small piece of film, about one square inch, in just enough boiling water to dissolve it. Place the solution in a shallow dish and allow it to stand uncovered overnight or until all the water has evaporated. Is there a thin film of polyvinyl alcohol at the bottom of the dish?

Experiment 14. Dampen a small piece of polyvinyl alcohol film and rub it between your fingers. Note that it feels somewhat sticky. This property combined with its tensile strength makes this plastic very useful as an adhesive, especially of the remoistenable type.

For remoistenable adhesives, polyvinyl alcohol that is partly hydrolyzed is usually used, since it is more soluble in cold water than completely hydrolyzed grades.

This adhesive property makes it useful as a binder in many textiles and also for sizing paper. Completely hydrolyzed polyvinyl alcohol is used in these instances to obtain greatest water resistance and strength.

Experiment 15. Take a strip of your

polyvinyl alcohol about ½ x 1½ inches in size and fold it in half. Place it between a folded piece of thin paper and apply an iron to it, starting with a low heat and gradually increasing the temperature until the film is sealed. Polyvinyl alcohol is heat sealable.

Some detergents and fertilizers are packaged in cold-water soluble polyvinyl alcohol. When the package is placed in water or into the damp ground the film disintegrates, allowing the contents to be released. The heat-sealed package keeps the contents air tight until used and the stretchability of the polymer makes it possible to package the substances compactly.

Experiment 16. Place a small square of the polyvinyl alcohol on a piece of newspaper or other absorbent paper and put a small drop of salad oil or other oil on the center of the film, being careful not to allow any of it to spill over the edge of the film. Leave it undisturbed for an hour or so.

Carefully push the film aside and note that no oil has penetrated through the film to the newspaper.

This resistance to oils and greases is applied in making grease-resistant paper.

Absolute grease resistance can be produced by coating paper with a continuous film of the polymer.

Experiment 17. Polyvinyl alcohol can be precipitated from water solutions or gelled by certain organic and inorganic compounds. One of the most effective agents for gelling this polymer is borax.

If you have some borax available, try this experiment. Completely dissolve a one-square-inch piece of the film in about two teaspoons of boiling water. Allow the solution to cool. Add about ⅛ teaspoon of borax to the solution and stir until dissolved. Allow the solution to stand for 5 to 10 minutes and then observe your results. Do you find a lump of gelled material at the bottom of the container?

The polyvinyl alcohol film was contributed by Reynolds Metals Company, Richmond, Va.

POLYSTYRENE FOAM

Foamed or expanded plastic materials can be made from rigid plastics, flexible plastics and elastomers.

Experiment 18. Open your bag of expandable polystyrene beads and place some of them in the palm of your hand. Note

their hardness and glassy appearance.

These beads are the expandable form of rigid polystyrene plastic. When expanded, they become polystyrene foam, the familiar material in which many breakable and delicate objects are packaged and with which many buildings are insulated.

There are two types of polystyrene foam —the expanded and the expandable. They are both composed of the same polymer, but the expanded type comes already expanded into a foam and extruded in sheets or boards ready for use, while the expandable foam is in the form of beads, like those in your unit, to be processed into a foam and molded into desired shapes by the user. The expandable polystyrene beads in your unit are marketed under the trade name Dylite® and were contributed by the manufacturer, Sinclair-Koppers Company, Pittsburgh, Pa.

Polystyrene belongs in the group of plastics known as vinyl plastics as does polyvinyl alcohol. The monomer composing polystyrene is vinyl benzene (styrene), $C_6H_5—CH=CH_2$ (see front cover).


= symbol for benzene

Several methods are employed for producing the cellular structure of foamed plastics. The result may be an open-cell structure, in which the cells are interconnecting, or a closed-cell structure.

In the manufacture of Dylite, 5 to 8 percent by weight of a volatile chemical, a saturated paraffinic hydrocarbon, is added to the polystyrene resin. The polymer is then extruded into beads or pellets. When heated, the hydrocarbon forms a gas and serves as a blowing agent, causing the beads to expand and form a fine internal homogeneous closed-cell structure.

Experiment 19. Place about 1/16 teaspoon of the beads in a Pyrex beaker or a transparent Pyrex pot half full of cold water. Any small pan may be used, but the reaction of the beads is more easily observed through a transparent container.

Note that the beads sink to the bottom.

Heat the water slowly, watching the beads as you do so. Do the particles rise to the surface as the water warms up? When the temperature of Dylite is raised to about 170°F, the beads begin to expand. As the beads expand, their density is decreased and they rise to the surface.

Continue to heat the water and bring it to a boil. Observe the beads as they gradually turn white and grow in size. Cover the container and continue to boil the beads for about 20 minutes or so until they have stopped expanding. Note their great increase in size.

Remove the balls of polystyrene foam and place them on a paper towel or other absorbent paper and allow them to dry. How much more volume do they occupy than the original beads?

Dylite will expand from 2 to 50 times the volume of its unexpanded size. The degree of expansion can be controlled by adjusting the temperature, pressure and length of time the beads are exposed to the temperature and pressure.

In actual practice, four heat sources have been used to expand Dylite—hot water, steam, hot air and radiant heat. The most common of these is steam.

Experiment 20. Note how light the spheres of foam are. Dylite particles have a bulk density of about 38 pounds per cubic foot (pcf). On expansion, their densities range from 0.8 to 20 pcf.

Experiment 21. Press one of the polystyrene balls between your fingers. It

yields to pressure like a sponge.

Cut one of the larger spheres in two with a pair of scissors. The cellular structure extends throughout the foamed bead, but the individual cells are so small you cannot distinguish them.

Experiment 22. When the polystyrene foam is heated to about 200°F, the surface of the foamed beads softens and becomes sufficiently adhesive to attach to one another. If the beads are expanded in a closed mold, the foamed plastic balls forced together adhere to each other and take the form of the mold cavity. After the mass is cooled, the fused molded article can be removed.

Obtain a polyethylene sandwich bag for the next experiment or empty the unused expandable polystyrene beads from the polyethylene bag into another container and use this bag.

Measure about ¼ teaspoon of the expandable beads into the polyethylene bag. Push them into one corner of the bag and then squeeze out the air from the bag by flattening it out. Tie the bag very tightly with a string leaving only about one square inch of space above the beads. Be sure it is water tight.

Place the bag in a pan of boiling water. Cover the pan and allow the beads to boil for about 15 to 20 minutes or until they have all expanded and filled the tied-off area tightly. Be sure the foamed beads have filled the space completely and that they have adhered to each other. Then remove the mass from the bag.

Note that the separate beads have become tightly fused to each other into a solid mass and have become molded into a more or less triangular shape.

This is similar to what happens when polystyrene expandable beads are molded. Under normal manufacturing conditions where both pressure and steam heat are applied, the process is much faster.

Experiment 23. Place the molded foam in water and then remove it. Does it absorb water? The water absorption of foamed polystyrene is extremely low. The non-interconnecting cell structure prevents the water from penetrating into the polystyrene foam.

This closed cell structure also makes polystyrene foam a poor conductor of heat and therefore a good insulator. Insulation quality, however, varies with the density.

Experiment 24. Apply a little pressure

to the foam with your fingers. Does it feel somewhat springy or resilient? This quality provides impact resistance in protective packaging.

To process Dylite, expandable polystyrene requires in most cases specialized equipment designed especially for this purpose.

Most of the Dylite molding is done with pre-expanded beads. The mold cavity is entirely filled with beads which have been pre-expanded to the bulk density desired in the molded article. The beads are then fused by heating with steam.

POLYURETHANE ELASTOMERS

Elastomers are polymers which have elastic or rubber-like properties. When elastomers are stretched and released they return rapidly to their original size. The extent of this elasticity depends on the kind of molecules which are assembled into the polymer chains, as well as on how severely those chains are tangled together and crosslinked.

Polyurethanes contain the urethane group (–NHCOO–) as the repeating unit. This is obtained by reacting certain isocyanates with molecules containing hy-

droxyl end groups, such as polyesters or polyethers.

Basically, polyurethanes are of three types:

Castable systems—Thick liquids which can be mixed and poured into simple molds. When heated, these materials react to form a rubbery solid.

Millable gums—Like sticky chewing gum. They must be mixed with materials which cause polymerization, producing a rubbery solid. These materials are cured (vulcanized) by heat, very much as rubber is vulcanized.

These two groups are thermoset polyurethanes, requiring heat to "set" them into polymer chains. The thermoset polyurethanes usually have many crosslinks interconnecting the long polymer chains.

Thermoplastic polymers—Supplied in small dry particles. They require no curing. They are probably the most versatile members of the polyurethane family because they can be softened by heat into a formable condition and can be reprocessed repeatedly.

Thermoplastic polyurethanes are molded into products ranging from tiny fasteners, which hold buttons on clothing, to

large automobile bumpers. They are also extruded into hose, cable jacketing, sheet and other items. Thermoplastic polyurethanes offer a combination of exceptional wear (abrasion) resistance, chemical resistance, puncture and tear resistance, low-temperature flexibility and resilience.

Experiment 25. Examine the shoe plate, or "Hush Plate," in your unit. The material from which it is made is a thermoplastic elastomer called Estane® polyurethane, manufactured by B. F. Goodrich Chemical Company, Cleveland, Ohio, who donated the specimen. The black color is due to the added pigment. Estane resin has a pale straw color.

Feel the shoe plate and note its hardness. Bend it back and forth. It is flexible and resilient like hard rubber and light in weight. You will also find that it is tough and abrasion-resistant.

Experiment 26. Place the shoe plate in the freezing unit of your refrigerator and let it remain there for about an hour. Then remove it and bend it back and forth. Note that it has retained its flexibility and does not break. Estane materials do not stiffen until the temperature is lowered to —20°F. They become brittle when

the temperature reaches the —90°F range.

Experiment 27. Remove the backing from the shoe plate and attach it to the leather heel or front tip of the leather sole of one of your shoes, hammering in the staple securely and pounding the plate down so that it adheres evenly and tightly to the leather.

After two weeks or so of hard wear on your shoes, walking and playing, examine the shoe plate. Does it look worn at all? Compare the amount of wear on the shoe plate with that on the unprotected area on the other shoe. Note that the shoe plate, while protecting the leather from wear, is itself resistant to cuts and abrasion.

Check your shoe plate at intervals of two weeks and note how durable it is.

Experiment 28. As you walk a bare floor, note that the shoe plate reduces the sound and is not slippery.

Some of the Estane polyurethane polymers have been specially developed for use as adhesives. Many shoes for women and children are assembled using very flexible Estane polyurethane adhesives to hold the soles and tops together.

Other Estane polyurethane polymers have been developed for coatings. They are

spread onto fabrics, metal foils and other plastics very much as paint is applied.

POLYCARBONATE

Experiment 29. Lift the toy car body in your unit above your head and then drop it on a hard surface such as a concrete walk. Did it break?

Step on it. Did it break this time?

Strike it with a hammer. What happens?

You will find that the car body is practically unbreakable. The plastic from which the toy, provided by the Tonka Corporation, Mound, Minn., is made is a virtually unbreakable polymer material, a polycarbonate called Lexan®, developed by the General Electric Company.

This high impact strength of Lexan is only one of the many properties typical of polycarbonates that make them one of the most versatile groups of thermoplastics. Polycarbonates are a special type of polyester in which groups of organic compounds called dihydric phenols are linked together by carbonate linkages. This particular chemical structure gives this polymer a variety of desirable qualities, such as impact resistance, which you observed in

Experiment 30, high transparency, creep resistance, wide temperature range, high dimensional stability, good electrical properties and resistance against fire.

Once molded, parts made of Lexan can be drilled, sawed, punched, turned or shaped with standard drilling, cutting and forming tools.

Experiment 30. Lexan in its natural resin state is crystal clear. Its transparency is almost equal to that of glass This makes the polycarbonate an excellent substitute for glass where the danger of breakage is great, because of its unusual impact strength. Lexan is used for the face shields in astronaut helmets, for lenses and for windows of railroad passenger cars and locomotives. The polymer is 250 times as strong as safety glass

Lexan mixes well with pigments and is made in a wide spectrum of colors. Note the color of your specimen.

Experiment 31. Lift the car body and note how light it is. This quality is an asset in many applications, especially when large housings for appliances such as air-conditioners are constructed from Lexan.

Lexan is a nonconductor of electricity and is safer to use as housing on electrical

appliances than metals which are good conductors of electricity. In addition to its insulating characteristic Lexan is light and nearly unbreakable, properties especially desirable in household articles.

Polycarbonates are thermoplastic and can be processed in conventional thermoplastic processing equipment. They can be thermoformed in a variety of ways, including injection molding, extrusion, blow molding and casting.

Polycarbonates are produced world wide and because of their many unusual properties are finding more and more uses in such broad areas as electronics, lighting, safety, automotive parts, precision parts and communications. To make the material even stronger, and to improve some mechanical properties polycarbonates may be reinforced with glass fibers.

POLYALLOMER

Some polymers are made up of a combination of two polymers and are called copolymers. Polyallomer is a copolymer composed of polypropylene and polyethylene. It maintains the crystalline structure of polypropylene but differs chemically from it because of the presence of ethy-

lene. Its properties are derived from those of the two polymers. Some qualities become enhanced in the copolymer.

You have observed many of the characteristics of polyethylene in Experiments 1 through 7.

Polypropylene is a flexible thermoplastic belonging to the group known as polyolefins. While it is very lightweight, lighter than polyethylene, it is at the same time strong and tough. Objects made of polypropylene can be bent double without breaking.

Polyallomer has greater resistance to fatigue from flexing than polypropylene and is superior to polyethylene in flow characteristics, moldability, hardness and shrinkage. It also has a higher melting point and has greater impact strength than polyethylene.

Experiment 32. Examine the polyallomer hinge in your unit. Open and close it repeatedly. Does it crack? The hinge demonstrates unlimited resistance to damage from flexing and is called a living hinge. The specimen in your unit was provided by the Stokes Molding Company, Trenton, N. J.

Living hinges grow stronger with use

and are often built in as a part of the whole plastic component. Applications of the living hinge include automobile accelerators, cosmetic cases, loose-leaf binders, suitcases and typewriter cases.

Polypropylene is also used to make these hinges, but polyallomar has greater resistance to breakage from flexing.

The continually growing field of plastics is a fascinating and challenging one. If you wish to study the subject further, the references below will be helpful.

With all the progress in this science, there exists a serious shortage of plastics engineers. If you are interested in making a career of polymer sciences, you may wish to write to the Plastics Education Foundation, 656 West Putnam Ave., Greenwich, Conn. 03830, who cooperated in the preparation of this unit. Appreciation is expressed to Mr. Robert J. Ullery, Education Director of the Foundation, for his efforts in obtaining the participation of the various manufacturers and for reviewing this booklet.

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